

# The 2002 Ueberlingen Mid-Air



## WBA & CausalML User Group Bielefeld v5.5

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Bielefeld, 6 June 2005

## Accident History (1)

- Tupolev Tu154M
  - Departure: Moscow-Domodedowo, 18:48 hrs
  - Destination: Barcelona
- Boeing B757-200
  - Departure: Bergamo, 21:06 hrs
  - Destination: Brussels
- 21:21:50 hrs: B757 enters Controlarea Zurich
  - Flight Level 260 (26.000 ft)
  - Clearance to climb to FL320
  - 21:26:36 hrs: Request to climb to FL360 granted
  - 21:29:50 hrs: FL 360 reached
- 21:30:11 hrs: Tu154 enters Controlarea Zurich
  - Flight Level 360

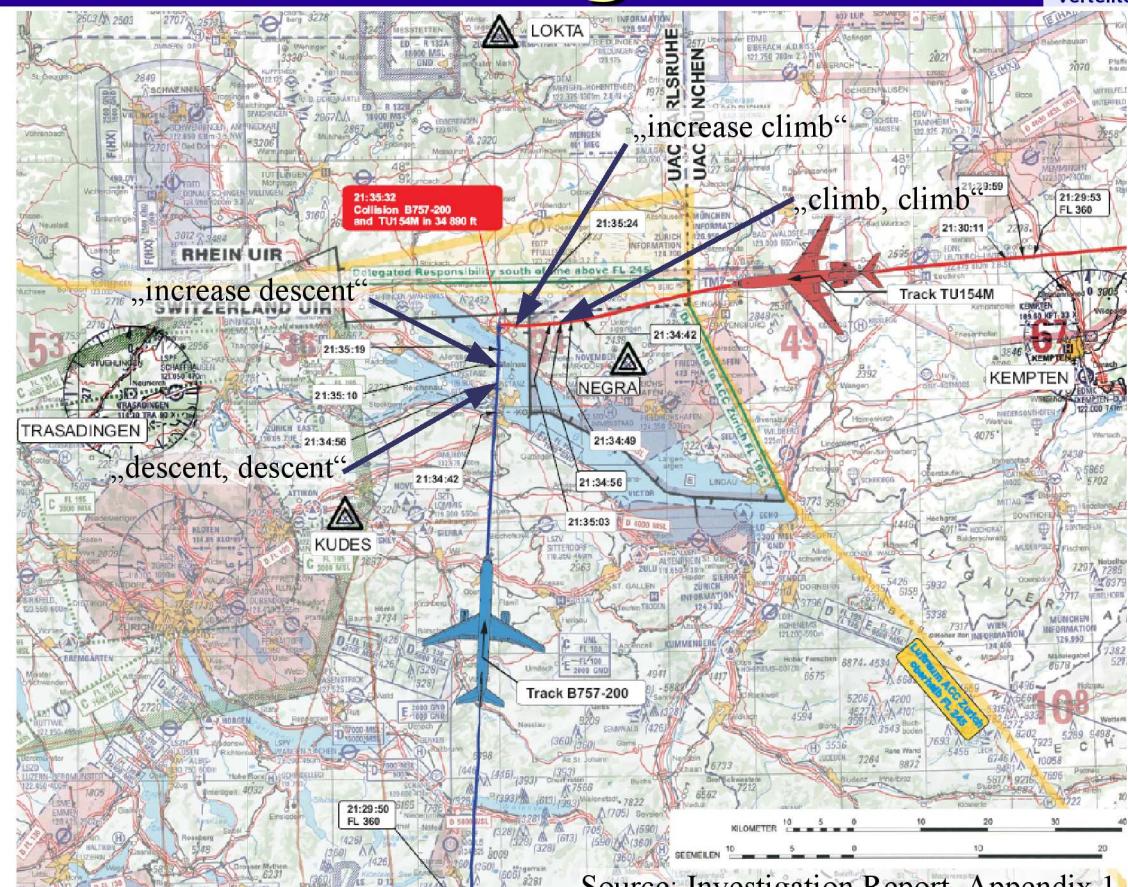
# Accident History (2)

- 21:34:42 hrs: TCAS TA generated
- 21:34:49 hrs: ACC Zurich to Tu154:
  - “descend flight level 350, expedite, I have crossing traffic”
- 21:34:56 hrs: Tu154 descends
- 21:34:56 hrs: TCAS RA generated
  - B757: “descend, descend”
  - Tu154: “climb, climb”
- 21:34:58 hrs: B757 descends
- 21:34:59 hrs: Discussion with Tu154 crew
- 21:35:10 hrs: B757 TCAS RA: “increase descend”
- 21:35:24 hrs: Tu154 TCAS RA: “increase climb”
- 21:35:32 hrs: Collision near Überlingen

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## Reconstructed Flight Paths



Source: Investigation Report, Appendix 1

- Winter Term 2004/2005
- Analysis done by group of 8,
  - 7 beginners in regard of WBA
- Time needed for analysis:
  - 15 Sessions, each 1.5 hrs (180 hrs)
  - Additional work during course (about 25 hrs)
  - Substantiation of List-of-Facts (about 35 hrs)
  - Total: about 240 hrs

## Analysis Proceeding

- Study of investigation report
- Beginning to compose List-of-Facts
  - Questions on sequence of events arrise
    - Some events given with absolute time
    - Some events given with relative time
    - Sequence of events not always chronological
- Composition of the timetable
- Extension of List-of-Facts
- Identification of causal relationships (WB-Graph)
- Error detection
  - Application of
    - counterfactual test
    - completeness test
  - Formulation of substantiated List-of-Facts

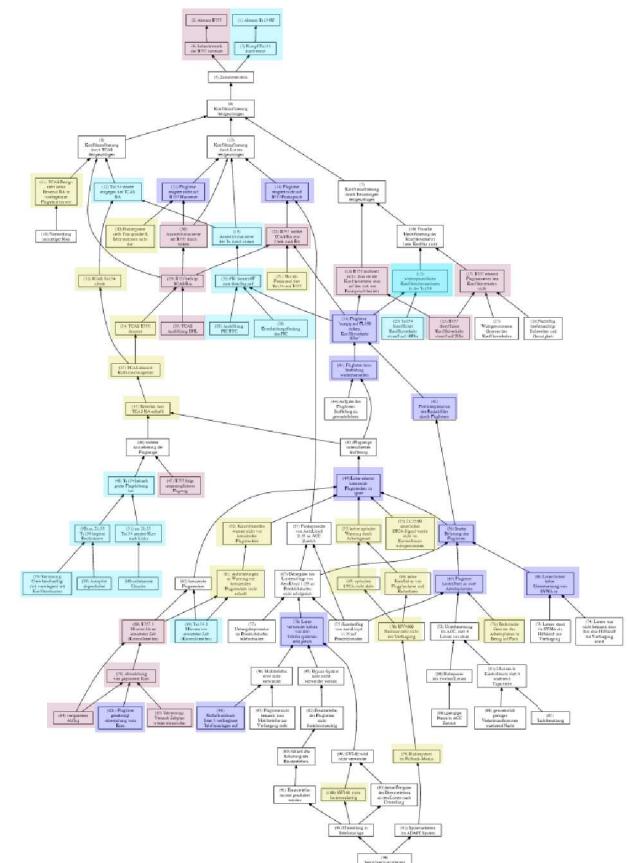
# Why-Because Graph

## Statistic:

- total of 94 knots
- 28 source factors
- 66 internal factors

## Main actors:

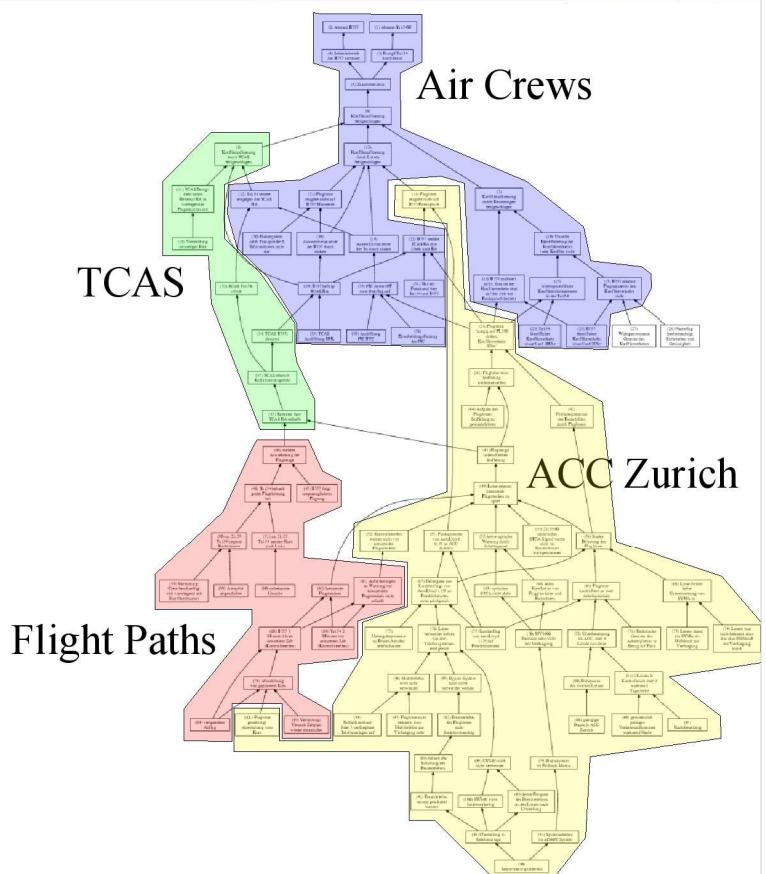
- Tu154M (ca. 16 factors)
- B757 (ca. 14 factors)
- Controller (ca. 11 factors)
- Technical (ca. 17 factors)



# Why-Because Graph

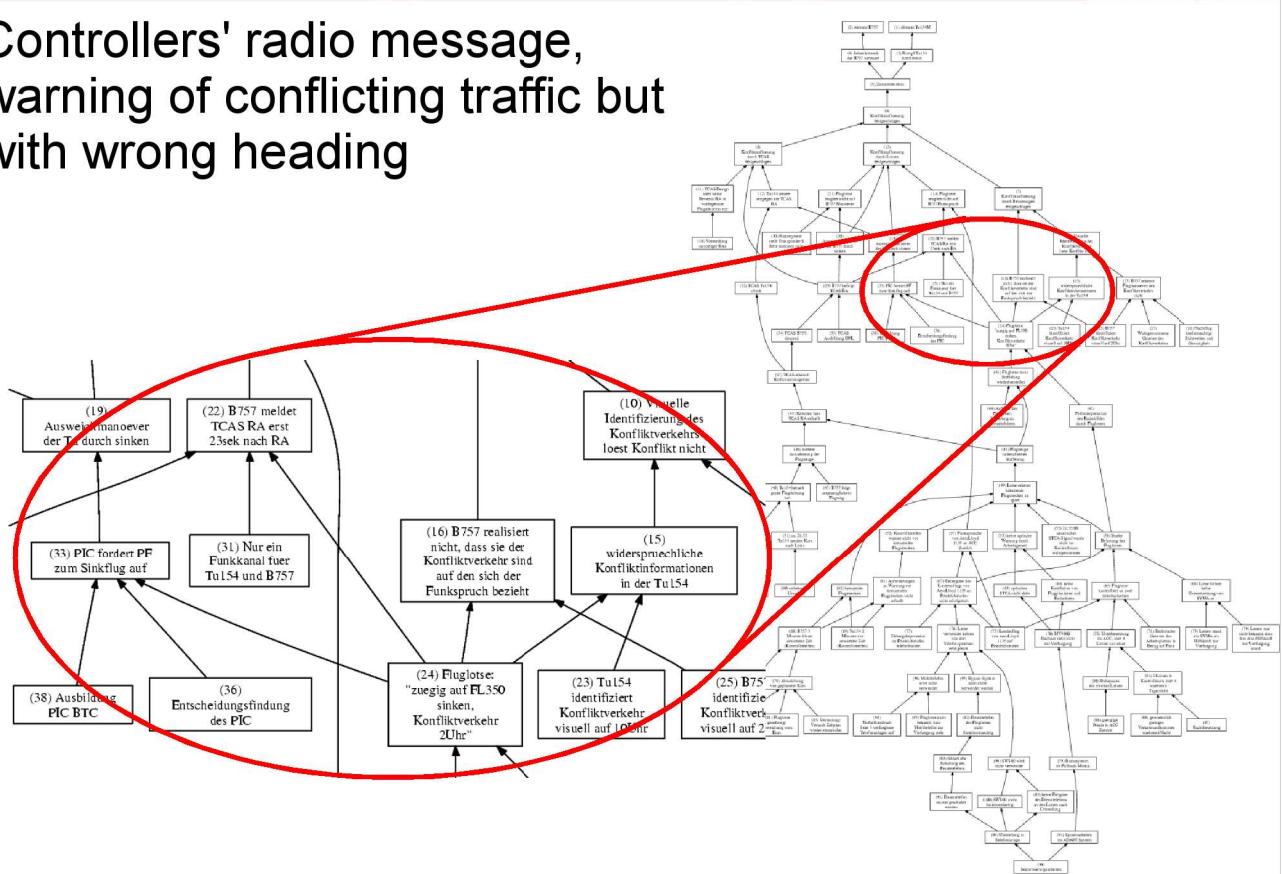
## Areas of Responsibility:

- TCAS
  - Devices
  - Design
- ACC Zurich
  - Controller
  - Organisation
  - Devices
- Air Crews
  - B757
  - Tu154M
- Flight Paths
  - B757
  - Tu154M



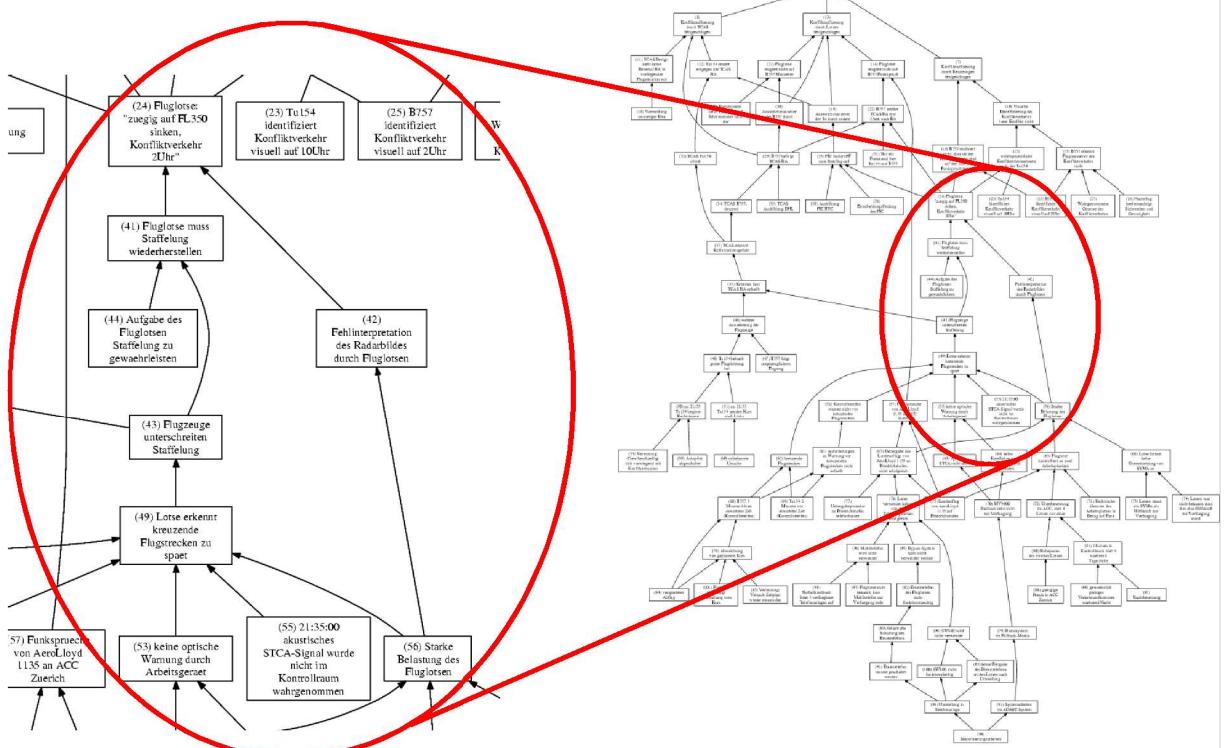
# Striking Points (1)

- Controllers' radio message, warning of conflicting traffic but with wrong heading



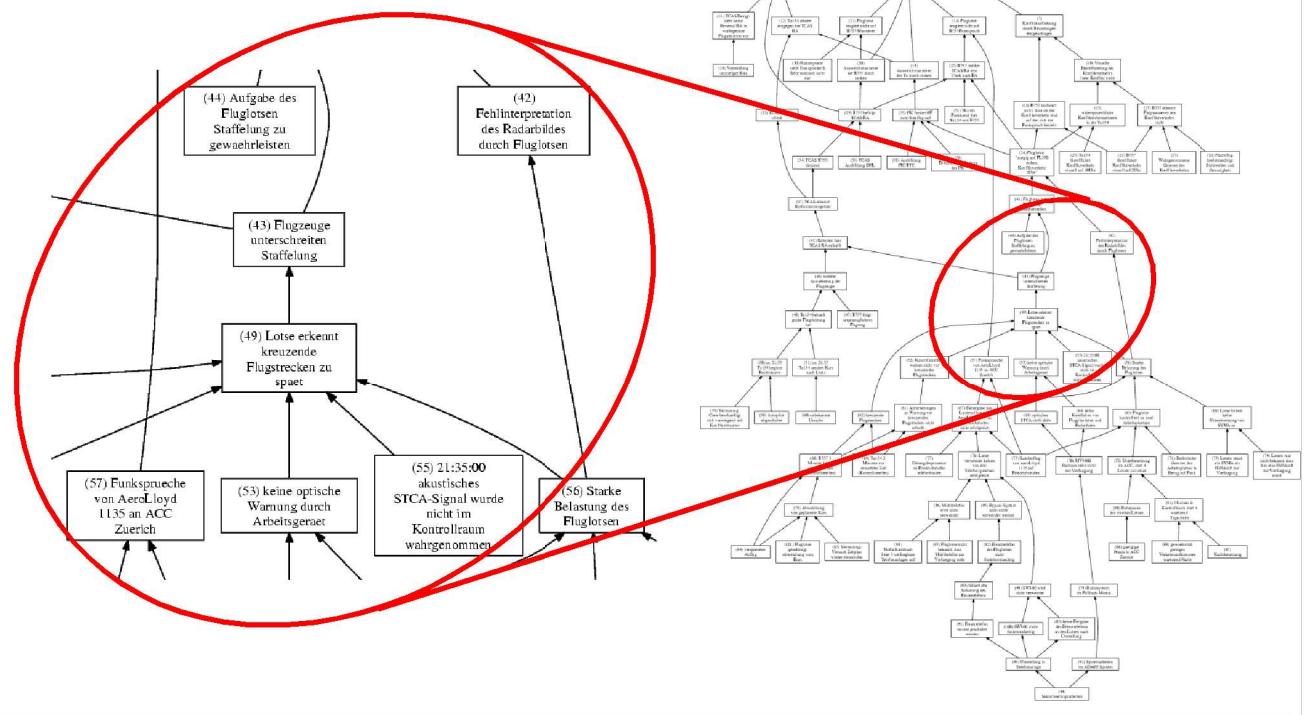
# Striking Points (2)

- Factors leading to mistake in radio message



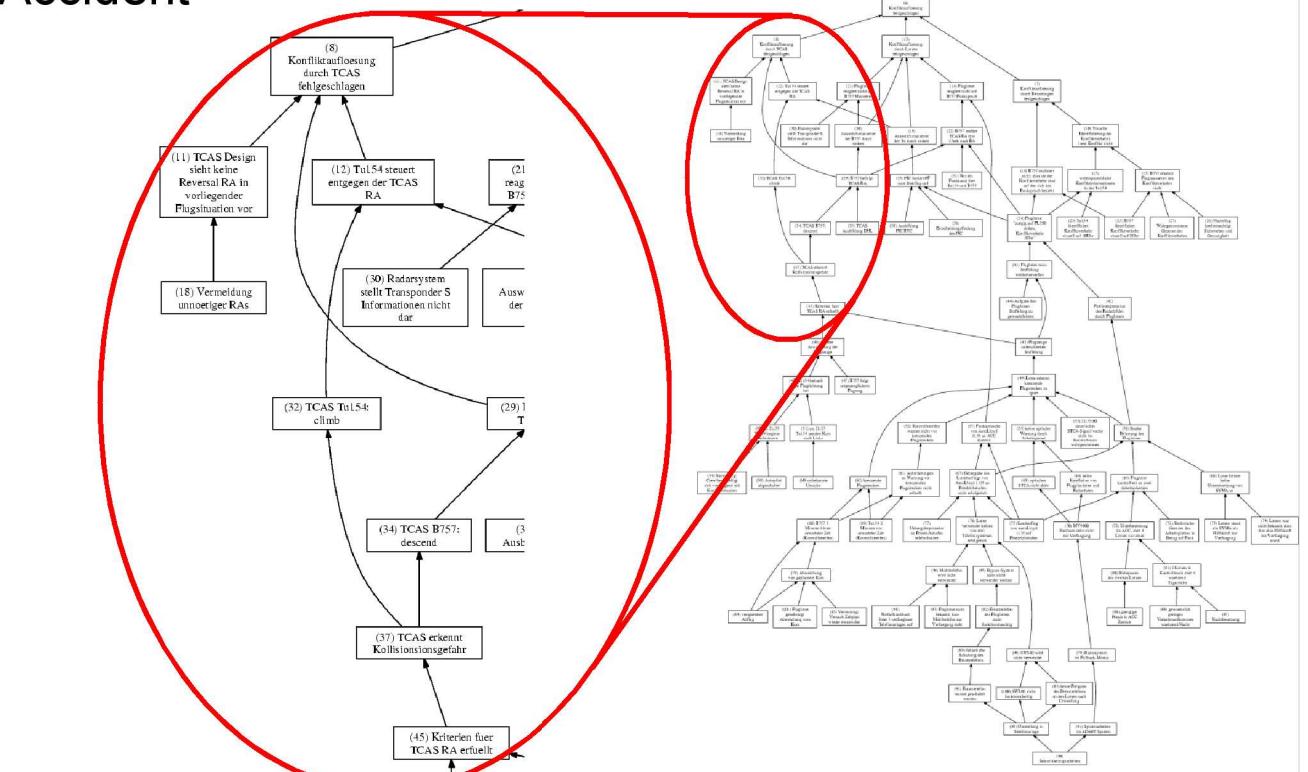
# Striking Points (3)

- “Waist” in Graph
- Width = 3



# Striking Points (4)

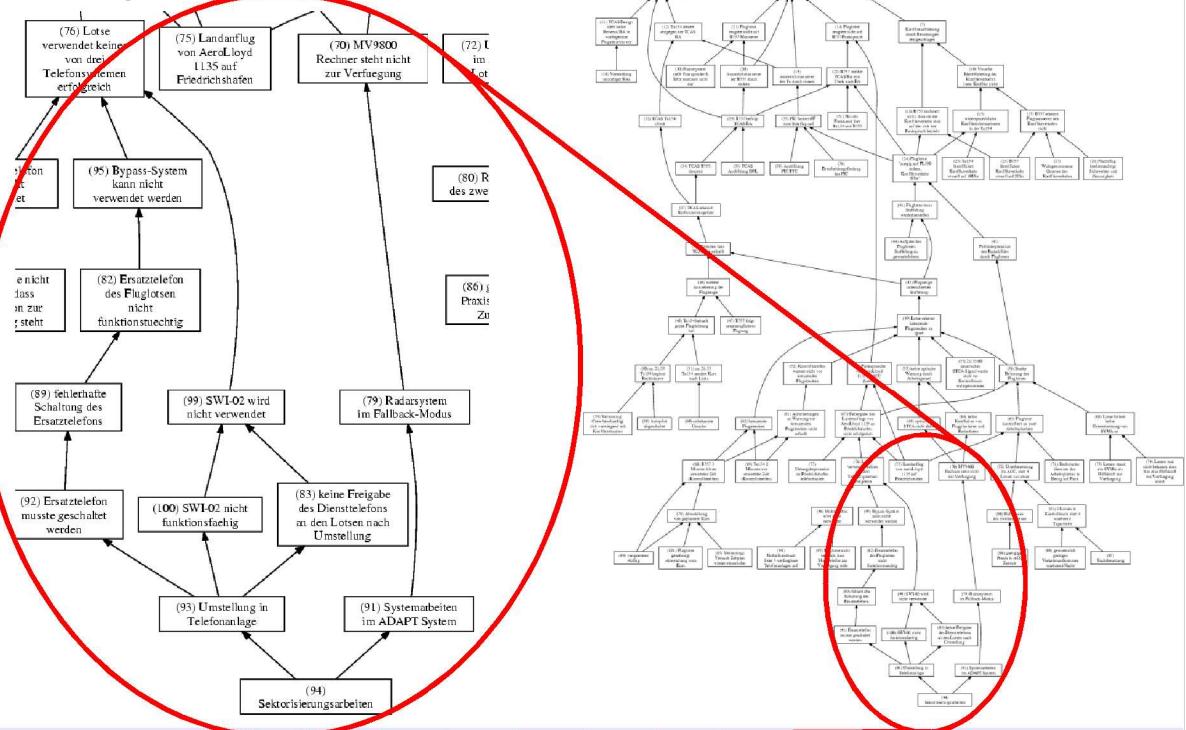
- Influence of TCAS on the Accident



# Striking Points (5)

## ■ Rearrangement of Sectors

- only part of events in ACC are caused by this!



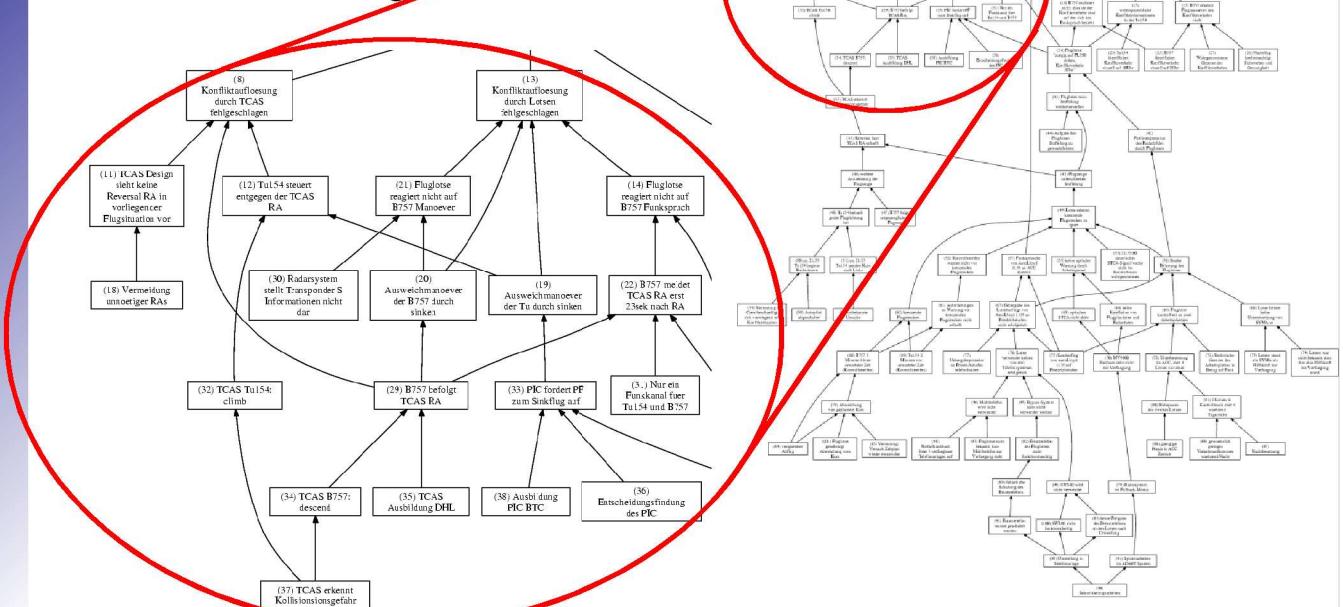
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# Striking Points (6)

## ■ Conflict Resolution by TCAS failed

- 3 participants:
  - B757
  - Tu154
  - TCAS Design



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- **Group consisted mainly out of “newbies”  
“Experts” probably won’t have these problems ;-)**
- Initial List-of-Facts
  - contained many facts, typically not relevant to analysis
  - consequence: it was only used in the beginning, later not minded much
- Causal Analysis based mainly on graph
- Factors were introduced in the graph
  - “Memory-based” approach
  - Evidence or reasoning not always carefully questioned
- Significance of results is based on factors' substance not the factors' title
- Thorough error-checking was needed

## WBG – Error Checking

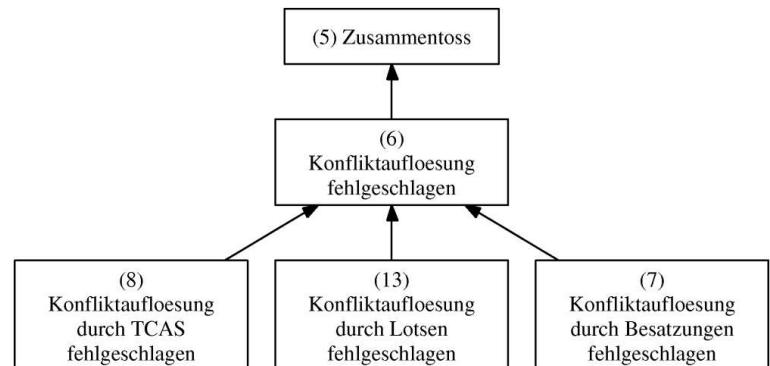
- Required Procedures
  - Counterfactual Test
  - Completeness Test
- Problems:
  - Argumentation based mainly on a factors' title
    - Factors' with meaningful title, that has no substance possible to occur
  - Hard to identify duplicate factors with different titles
- Solution used:
  - Every factor in the WBG was substantiated
- Result:
  - Not sustainable Factors were identified
  - Factors with identical substance were identified
- WBG was corrected (Factors removed or fused)

- every Factor part of the WBG has to be substantiated
- Classification of factors ease the argumentation
  - Systematic partitioning
    - partitioning factors
    - summation factors
  - Omissions
  - Causal closures
  - Facts
  - Assumptions

## Classification of Factors (1a)

- Systematic Partitioning

- only 3 systems can influence the event
  - TCAS
  - Controller
  - Crews



- if none of these systems achieve the resolution of the conflict situation, the conflict situation itself cannot be resolved.

- 2 Classes of Factors:
  - Partitioning factors
  - Summation factors

# Classification of Factors (1b)

## ■ Partitioning factors

### ■ Excerpt from List-of-Facts:

#### (6) Konfliktauflösung fehlgeschlagen

Systematische Aufteilung

*Der Grund für das Fehlschlagen der Konfliktauflösung lässt sich durch das Zusammenwirken folgender Ereignisse erklären:*

- a) Konfliktauflösung durch die Besatzungen fehlgeschlagen
- b) Konfliktauflösung durch das TCAS-System fehlgeschlagen

c) Konfliktauflösung durch Kommunikation mit Fluglotsen fehlgeschlagen

*Diese Aufteilung bietet sich an, da nur diese 3 Systeme kontrollierenden Einfluss auf die Flugsituation nehmen konnten.*

## ■ Summation factors

### ■ Excerpt from List-of-Facts:

#### (7) Konfliktauflösung durch die Besatzungen fehlgeschlagen.

Summationsfaktor

*Inhalt: Trotz vorhandenem Sichtkontakt waren die Besatzungen nicht in Lage die Konfliktsituation aufzulösen.*

# Classification of Factors (2a)

## ■ Omissions

■ Omissions are events that were supposed to happen under normal system operation but didn't happen.

■ Three items are required for justify the occurrence of an omission:

- A rule or habit for a reaction of an event exists
- Such an event occurred
- The observation that the expected reaction did not took place

■ Omissions in the analysis:

- *Fluglotse reagiert nicht auf B757 Funkspruch*
- *Fluglotse reagiert nicht auf B757 Manöver*
- *Mobiltelefon wird nicht verwendet*

# Classification of Factors (2b)

## ■ Omission

### ■ Excerpt from List-of-Facts:

#### (21) Fluglotse reagiert nicht auf B757 Manöver

Begründung einer Auslassung (omission)

a) Ereignis: Fluglotse hätte zum Zeitpunkt des Unfalls auf Radarbildschirm WS-RP mindestens eine Abweichung in der Flughöhe der B757 um 2-3 FL erkennen können

b) Feststellung: Flugzeuge im RVSM Verkehr müssen Höhe mit maximal 65ft Varianz einhalten, 2-3FL entsprechen 200-300ft

c) Pflicht: Der Fluglotse hat die Aufgabe, den Verkehr unter seiner Aufsicht zu regeln

d) Feststellung: Der Fluglotse hat keine Anweisung an B757 zur Regelung der Situation gegeben.

- b) contains the argumentation for the statement made in a) as this statement was derived from various facts.
- If direct argumentation for a) could be given, b) is not needed.

# Classification of Factors (3a)

## ■ Other factors:

- Causal closures
- Facts
- Assumptions

## ■ Causal closures

- Factors that necessarily follow from a group of events.

## ■ Facts

- Facts in the graph are events that can be justified directly by results of the investigation report.

## ■ Assumptions

- credible assumptions follow from statements made in the investigation report but are not directly mentioned.

# Classification of Factors (3b)

## ■ Causal closure

### ■ Excerpt from List-of-Facts:

(16) B757 realisiert nicht, dass sie der Konfliktverkehr sind, auf den sich der Funkspruch bezieht

Kausaler Schluss

(24) Fluglotse warnt Tu154 vor Konfliktverkehr von links

(25) B757 erkennt von links kommenden Konfliktverkehr

## ■ Facts

### ■ Excerpt from List-of-Facts:

(22) B757 meldet TCAS RA erst nach 23 Sek. nach RA

a) 21:34:56 – erhielt die Crew RA „descent, descent“

b) 21:35:19 – Meldung der Crew an ACC Zürich : „TCAS descent“

## ■ Assumptions

### ■ Excerpt from List-of-Facts:

(85) Vermutung: B757 Crew versucht Zeitplan wieder einzuholen

Im Unfallbericht wird kein Grund für die Erlaubnis für den Direktanflug auf TANGO VOR gegeben. Gründe könnten sein,

a) dass der Pilot versucht, seinen Flugplan einzuhalten

b) dass der Direktanflug Standardprozedur bei geringem Verkehrsaufkommen ist.

# Causes identified by BFU

## ■ Immediate Causes:

- ATC didn't note separation infringement in time.  
Instruction to Tu154M was given at time, when separation couldn't be ensured anymore
- The Tu154M crew followed the ATC instruction to descend and continued to do so even after TCAS advised them to climb

## ■ Systematic Causes:

- ACAS/TCAS II not sufficiently integrated into the system aviation
- Regulations concerning ACAS/TCAS published by ICAO were
  - not standardised,
  - incomplete,
  - partially contradictory
- Management of air navigation service did not ensure that by night all open workstations were staffed by controllers
- Management of air navigation service tolerated that during times of low traffic flow only one controller worked

- The first immediate cause was essential for this accident
  - It represents one of the strands in the waist of the graph.
  - The comment on the timing of the instruction is only a statement. It doesn't seem to be in itself a cause.
- The second immediate cause could also be identified
  - Causally, the fact of the B757 following the TCAS advisory is equally important but left out of the BFU finding.

# Comments on Causes

- The first systemic cause is very interesting as it states,
  - that the ACAS/TCAS II system was not only insufficiently integrated in the system aviation but
  - that it did not correspond in all points with the system philosophy
  - ICAO regulations were not standardised and partially incomplete
- These findings are present in the WBG
  - (30) identifies that the ATCs' radar system does not represent the TCAS informations
  - (11) identifies that design had prevented a possible Reversal RA
  - The regulations are included in (35), (36) and (38).

- The second and third systemic cause concerning the Management of ACC Zurich concern only the number of controllers present in the controlroom.
  - These correspond with (81) respectively (80).
- It is interesting that concerning the causes BFU does not identify the execution of the rearrangement of the sectors at ACC Zurich to be a direct cause to the accident.
- Individual mistakes of the Controller that could possibly result out of deficiency in training or information are not listed under the direct causes.

## Safety Recommendations

- ACAS/TCAS related:
  - Regulations should require pilots to follow TCAS RA
  - Russian pilots should train ACAS maneuvers in simulators
  - TCAS 2000 operation manual should be rephrased
  - Initiation of development for downlinking RAs to ATC
- ATC
  - Maintenance work on the ATC system should be organised and operational effects as well as available redundancies are known by the staff
  - Increase in number of controllers at ACC Zurich
  - Training of the air traffic controllers
- Technical
  - STCA should indicate failure or unavailability
  - Telephone system should reroute to bypass system in case of failure or shutdown
    - What happens, if the bypass system itself is defective?
  - Updates on radar system within 8 sec or less

**Thank you  
for your interest.**

*... happy landings.*